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The Nutritive Value and Supplementation of ogi (pap), the Major Nigerian Weaning Food

Elizabeth E. Gyaami

LOMA LINDA UNIVERSITY

Graduate School

THE NUTRITIVE VALUE AND SUPPLEMENTATION OF OGI (PAP), THE MAJOR NIGERIAN WEANING FOOD

by

Elizabeth E. Gyaami

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Master of Science.

Albert Sanchez, Chairman

Albert Sanchez, Associate Professor of Nutrition

U. D. Register

U. D. Register, Professor of Nutrition

James W. Blankenship

James W. Blankenship, Assistant Professor of Nutrition

Paul Y. Yahiku

Paul Y. Yahiku, Assistant Professor of Biostatistics

PREFACE

The problem of protein-calorie malnutrition (P-C.M.) has been of much concern to the writer who is a Nigerian and has lived in many parts of that country. All through her course of study in nutrition, she has had a keen interest in studying about the problem. As a teacher of Home Economics for four years in Nigeria, all the girls that have gone through her classes have received lectures and cooking classes as to how to combat this problem using meat, milk, and eggs.

Although there is a general knowledge that legumes and nuts are good vegetable protein sources, most people, including the writer, did not recognize the value of supplementation of cereals with legumes and nuts. When she started college at the Adventist College of West Africa in Nigeria, she came in contact with a religious group who appeared peculiar. Their eating habits seemed to be centered around this principle of supplementation of plant proteins and the exclusion of meat from the diet. It then occurred to the writer that the same principle can help solve the problem of P-C.M. in Nigeria, using the available cereals, legumes, and nuts of low cost, which can be obtained by all. As a graduate student in nutrition her main ambition was to do a research study along this line.

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TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

Chapter 1

INTRODUCTION

According to the Joint FAO/WHO Expert Committee on Nutrition (1962 in Platt and Stewart, 1971), protein-calorie malnutrition (P-C.M.) is a generic term now firmly established to cover the whole range of mild to severe malnutrition. It includes, among other conditions, the two most severe clinical syndromes, kwashiorkor and marasmus. Kwashiorkor is a nutritional deficiency syndrome observed in children subsisting on a low protein diet, while marasmus is caused by a deficiency in both calories and protein. Kwashiorkor and marasmus are often postweaning phenomena.

The hyphen in P-C.M. is there by design and not by accident, indicating the inseparable link between the two, protein and calories. This is due to the fact that when the proportion of protein in a diet is very low the appetite is depressed, and when the calorie intake is low, protein may be expended as energy and thus will be unavailable for anabolic processes (McLaren and Pellett, 1970; Platt and Stewart, 1971).

THE PROBLEM

P-C.M. is the main nutritional syndrome and it produces an extraordinarily high mortality and morbidity in Nigeria (Gurney, 1971). This seems to be the result of culture, economics, and, most of all, lack of knowledge in combating P-C.M. Meat is used in different amounts all over the country. Eggs are not usually given to children even though guinea fowl eggs are collected in the scrubland areas of the northern region when in season. Some people in the villages have eggs from their own poultry, but generally they will not feed them to their children because they believe that it will make them steal. There is also the belief that eggs will cause diarrhea in children (Oke, 1972). Other West African countries, such as Sierra-Leone, have similar beliefs (Glynn, 1967). In general, eggs, as well as meat and milk, are also expensive and the poorer groups cannot afford to buy enough to feed their large families (Van Veen, 1964; McClean, 1966; Edozien, 1970). There is a general knowledge that legumes and nuts are good vegetable protein sources but the value of supplementation of cereals with legumes and nuts has not been recognized.

The research on supplementation of Nigerian diets has, thus far, been with indigenous foods for adults (Fuller et al., 1972; Sanchez et al., 1972), while very little study (Akinrele and Edward, 1971) has been done on supplementing the Nigerian infant weaning foods. The major problem of P-C.M. in Nigeria starts during the weaning period when mothers use eko, the cooked form of ogi, for weaning their babies (Collis, 1966; Akinrele and Bassir, 1967; Akinrele and Edward, 1971; Osifo, 1971; Omolulu, 1972). Collis (1966) stated that during the process of making ogi, the largest portion of the protein is poured off with the water, reducing the protein of corn from a normal of 7 to 9% down to 1-1/2 to 3%. He further stated that the resulting powder is almost pure starch and its use is the main cause of kwashiorkor in Nigeria.

THE PURPOSE

A purpose of this investigation was to determine the nutritive value as well as the protein and amino acid composition of ogi as compared to corn. In addition, the supplementary value of other inexpensive foods that are indigenous to Nigeria were investigated in reference to the improvement of the protein quality of ogi.

Chapter 2

REVIEW OF THE LITERATURE

KWASHIORKOR AND MARASMUS

Signs and Symptoms of Protein-Calorie Malnutrition (P-C.M.)

Kwashiorkor is a word in the language of the West Africa country of Ghana that means "golden boy" or "red boy." It is a syndrome produced by severe protein deficiency (Dorland, 1969) and is most commonly seen in children 1 to 3 years old with it being most often a post-weaning phenomenon. Both the Ga (the language of the Accra people in Ghana) word, kwashiorkor, and the Luganda equivalent, Obwosi, mean a child displaced or deposed by another pregnancy (Jelliffe and Bennett, 1972). Kwashiorkor was first reported in Africa and is now known to occur throughout the world, but mainly in the tropics and subtropics. Marasmus is another syndrome produced by a deficiency in both protein and calories. It usually occurs in children below 18 months of age but can also be a post-weaning phenomenon.

The metabolic rates of four normal children and thirteen with kwashiorkor were determined while they were asleep. The metabolic rate of the kwashiorkor children was subnormal and rose after a few days or weeks of treatment into the normal range (Ablette and McCance, 1971). Other clinical and laboratory observations relating to marasmus and kwashiorkor are shown in Table 1 (McLaren and Pellett, 1970).

Growth and Development

Studies in Nigeria (McFie, 1967; Edozien, 1970) and other parts of the world (Dawns, 1964; Leary and Lewis, 1965; Brock, 1966; Morley, 1968; Thompson et al., 1968; Satge, Mattrel, and Dan, 1970) reveal that growth failure is a cardinal and early feature of all forms of P-C.M. and is often first noted as a plateau of the weight curve during infancy and childhood. Brock (1966) pointed out that in a newly weaned child, P-C.M. retards tissue maturation as well as growth. The retardation of tissue growth has also been observed in the delay in the fusion of the epiphyses during bone development in 137 undernourished children in Alabama (Dreizen and Stone, 1962).

In a study of children recovering from P-C.M., growth rates were 15 times as fast as in normal children of the same age (Ashworth, 1969). However, from 6 to 11 years after discharge from the hospital 152 Uganda children who had been treated for severe protein deficiency in childhood were traced and examined. They were small compared with control children of the same area and economic status and with white North American children (Krueger, 1969).

In a project using 46 weanling male rats comparing high-protein diets with low-protein diets, the weight of individual organs indicated

Table 1. Some Characteristics of Marasmus and Kwashiorkor[1]

	Marasmus	Kwashiorkor
General Features		
Occurrence	world-wide	limited
Usual age	infancy	2nd and 3rd years
Adaptation to stress	good	poor
Response to treatment, immediate	poor	good (occasional sudden death)
ultimate	fair	good
Long term effects		
Mental and physical retardation	++	+
Liver damage	nil	nil
Clinical Signs		
Edema	absent	present
Dermatosis	rare	common
Hair changes	common	very common
Hepatomegaly	common	very common
Mental changes	uncommon	very common
Wasting of fat	severe	mild
of muscles	severe	mild
Anemia	common and mild	common and severe
Vitamin deficiencies	+	++

Table 1 (continued)

	Marasmus	Kwashiorkor
Laboratory Findings		
General		
Total body water	++	+
Extra cellular water	+	++
Body potassium depletion	++	+++
Malabsorption	+	++
Fatty infiltration of liver	absent	+++
X-ray bone loss	+	+
Renal function	impaired	impaired
I.V. glucose tolerance	normal	normal
Response to epinephrine	exaggerated	lowered
Serum		
Albumin	slightly low	very low
Enzymes (in general)	normal	low
Copper, zinc, sodium	normal	low
Nonessential/essential amino acids	normal	high
Triglycerides	normal	normal
Cholesterol	normal	low
Nonesterified fatty acids	normal	high
B-lipoprotein	high	low
Insulin	low	high
Growth hormone	low or normal	high
Glucose	low	very low

Table 1 (continued)

	Marasmus	Kwashiorkor
Urine		
Urea/total N	above 65%	below 50%
Imidazole acrylic acid	-	+
Hydroxyproline index	low	low
Liver		
Urea cycle enzymes	low	low
Amino acid synthesizing enzymes	high	high

[1]McLaren and Pellett (1970).

a significant weight loss produced by long-term protein deficiency (Svaboda et al., 1966).

Physical Endurance

At a temperature of 23°C. the rats on a normal protein level swam longer than those on low-protein level ($P < .001$) (Sanchez et al., 1972). In another swim test by Halac (1961) two groups of rats were fed a high protein diet or a normal protein diet for 60 days. In a cold water bath (5°C.), the rats on high protein diet swam the longest time ($P < 0.05$). Following 9 days' provision of a high protein, high fat, or high carbohydrate diet, rats were made to swim to exhaustion in water at a temperature of 25 to 26°C. Under both ad libitum and restricted feeding conditions, animals fed the high protein diet had the greater endurance while there was no apparent difference between endurance of animals fed the high fat or high carbohydrate diets (Beaton and Feleki, 1966). The above reports seem to indicate that increased protein is associated with increased endurance in rats.

However, other observations appear to be contrary to the above findings. Goshi (1961, in Beaton and Feleki, 1966), noted that increasing dietary protein from 0 to 25% of the diet decreases the endurance of swimming mice. Crews and others (1969) found in their investigations that growing rats eating a low protein diet (8% casein) were markedly stunted but otherwise appeared healthy. They had a greater capacity for prolonged running than the rats on the normal protein diet.

It had been observed that there was a significant positive correlation between water temperature and endurance in the temperature range of 10 to 28°C., but at 30°C. the rats swam indefinitely (Beaton and Feleki, 1967). McArdle and Montoye (1966) reported a negative correlation between body weight and endurance in rats made to swim under similar conditions.

Muscle

The body's principal store of protein is muscle. In the marasmic and kwashiorkor children this stored protein is used up (Cheek et al., 1970). It has been observed that in the animals on low protein diets, the weights of the skin, skeletal muscle, liver, brain, intestines, kidney, heart, gastrocnemius muscle, were greatly reduced (Cabak et al., 1963; Va santha, 1969; Fuller et al., 1972; Sanchez et al., 1972), with the skin, liver, and skeletal muscle losing more weight than the body as a whole (Cabak et al., 1963). Findings indicated that the loss of cell size accounted for most of the loss of muscle mass (Montgomery, 1962; Cheek et al., 1970).

In the determination of the effects of feeding a protein deficient diet on protein, RNA, and DNA accumulation in rat gastrocnemius muscle, it was concluded that protein synthesis evidently had priority over DNA synthesis when muscle growth is retarded by mild deprivation of dietary protein (Howarth, 1972). Previous work shows that with rehabilitation after 9 months of treatment, growth of muscle and fat took place but the normal level of protein, RNA, and Mg in relation to DNA were not attained (Cheek et al., 1970).

Brain Damage

Observations on P-C.M. children demonstrate that their intellectual performance is impaired relative to well-nourished children (Gravioto and DeLicordie, 1971). Although there have been difficulties in developing adequate tests and designs to clearly delineate the effects of nutrition and other variables which may influence intellectual development in children, findings in experimental animals strongly support the fact that there is brain damage in malnourished animals as compared to well-fed ones (N.R.C., 1966; Sereni et al, 1966; Baird, Woddowson, and Cowley, 1971).

In P-C.M. the brain damage is due mainly to protein deficiency caused by feeding grossly unbalanced diets in early life (N.R.C., 1966; Edozien, 1970). This brain damage is comparable in severity to the more widely recognized effect of P-C.M. on physical growth and development (Edozien, 1970). Rabinovitch and Rosvold (1951, in Anonymous, 1972) found that a low protein diet had a more deleterious effect than a low calorie one.

Inasmuch as both protein and lipid are involved in cell construction it is clear that a diet low in protein will also be low in lipid (Muralt, 1972). Studies reveal that as long as the protein matrix of the brain develops normally and as long as there is a certain supply of essential fatty acids, the brain weight is not affected. If the EFA supply is cut off temporarily, the brain weight is reduced but returns to normal values under rehabilitation, whereas the brain suffers permanent damage mainly if the insult occurred during the period of rapid growth (Brown,1966; Muralt, 1972). This has been suggested to include the time from the second half of fetal life until about 18 months of age (Muralt, 1972).

P-C.M. during early brain development curtails both protein synthesis and DNA synthesis. The result is a permanently stunted brain containing fewer cells of normal size (Winick, 1970; Muralt, 1972). Figure 1 (Winick, Rosso, and Waterlow, 1970; Muralt, 1972) shows a schematic presentation of a hypothesis to explain some of the mechanism by which undernutrition may affect brain growth. The white areas are the effects of P-C.M. while the shaded areas are hypothesized to occur.

Method of P-C.M. Detection

The head circumference in marasmic infants who died as a result of severe malnutrition was reduced proportionally to weight and protein content of the brain (Winick and Rosso, 1969; Read, 1973).

Cranial circumference, wet and dry weight of brain, DNA content, cholesterol and phospholipids were lower than normal in malnourished children (Rosso, Hermazabal, and Winick, 1970). This decreased brain volume creates a space between the brain and the interior of the rigid cranium, which is filled with cerebrospinal fluid (Rozovski et al., 1971).

Thus findings of Winick and Rosso (1969) seemed to strongly support the validity of using changes in head circumference as a measure of post-natal brain growth in normal and malnourished infants.

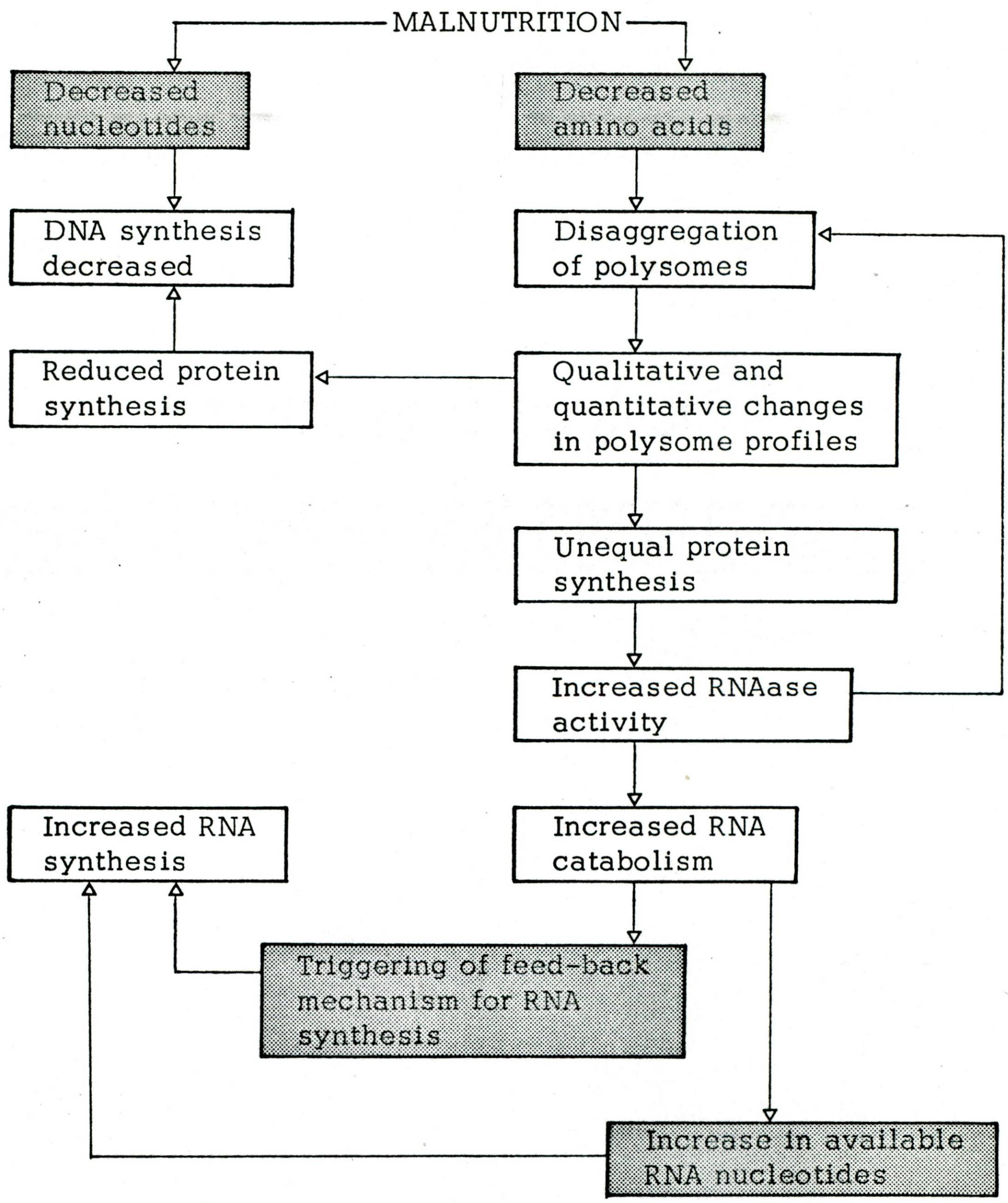

Figure 1. Mechanism by which Undernutrition May Affect Brain Growth (Winick, Rosso, and Waterlow, 1970; Muralt, 1972)

The vulnerability of the brain during postnatal (and prenatal) life indicates that the proper nutrition of the pregnant woman and newborn child should have priority in developing countries.

PROTEIN-CALORIE MALNUTRITION (P-C.M.) IN NIGERIA

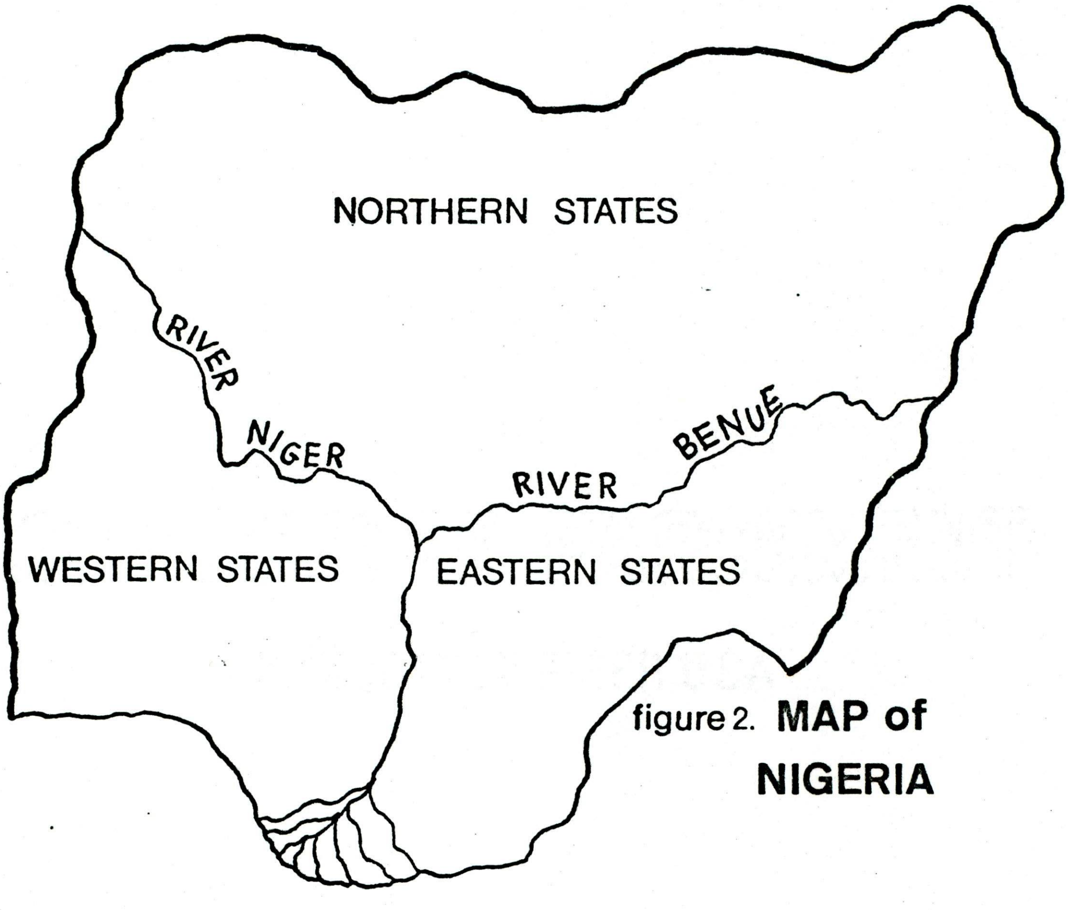

figure 2. **MAP of NIGERIA**

Nigeria is in West Africa. It has an area of 356,000 square miles and a population of nearly 62,000,000. Nigeria consists of 12 states: Lagos State, Mid-West State, and 2 other states in the west, 3 states in the east, and 5 in the north.

Economics

Several factors in Nigeria contribute to the onset of P-C.M., among which is low purchasing power (Akinrele and Edward, 1971; Omolulu, 1972). In Nigeria the available evidence suggests that insufficient money to buy meat, fish, milk, and eggs is probably the biggest factor leading to P-C.M. in children of growing urban populations (Van Veen, 1964; McClean, 1966; Edozien, 1970), but this is probably not true in the rural areas (Edozien, 1970), because the cost of living in the rural areas is much lower than that of city populations.

In Nigeria the farm population is increasing at such a rate that there are too many people for the land so that many are jobless or have a reduced earning power (Oke, 1972). As a result there is a universal tendency for people to drift to urban areas which have insufficient industries or job opportunities to absorb the rapidly growing population. The result is growing slums, unemployment and other social problems (Aall, 1970; Oke, 1972). Lagos and Ibadan are examples of this problem.

Education

Illiteracy is a major problem. Even if an illiterate is wealthy it does not necessarily mean that he knows what is best for himself and his family nutritionally. The parents in most of rural Nigeria do not realize the needs of growing children (Nicol, 1959a). During the Nigerian-Biafran (eastern Nigeria) war, powdered eggs given out to mothers of

P-C.M. children were often sold in the market or given away due to lack of understanding between the relationship of P-C.M. and the food fed to the children (Shellenberger, 1969). [When Biafra was blockaded in May, 1967, most of the protein foods imported for the 15,000,000 Biafrans were cut off.]

Increased Population

The advent of modern medicine and improved sanitation has resulted in higher birth rates and lower death rates, resulting in increased population at a rate of 2.8% per anum (Oke, 1972). This means that the present population will be doubled within the next 35 to 40 years without a corresponding increase in food production, whereas the wealthy countries double their population in about 55 to 58 years.

Decreased Productivity of Soil and Meat Due to Poor Animal Husbandry

The shifting cultivation (slash-and-burn) system used by most of the Nigerian farmers has sustained the country for many years. However, sometimes due to land shortage fallow periods are not long enough, which result in low productivity of the soil. Fertilizers, which are unknown to many farmers, are too expensive for many. Therefore, some of them depend on animal manures alone which are insufficient to meet the demands (Oke, 1972).

Eastern and Western Nigeria generally have a wet tropical climate with rain forest vegetation which is prevalent along the coast and becomes dryer toward the northern states of Nigeria. These areas are to a large extent infested with the tsetse fly, which makes the raising of cattle difficult because of trypanosomiasis (Aall, 1970).

Eggs are not produced in large quantities because the hens depend almost entirely on scavenging for food. The average hen lays about 50 eggs a year compared with 217 in the United States (Oke, 1972).

Poor Food Preservation

It is estimated that about 30 to 50% of all the foods produced by farmers in Africa never serve as human food due to insects, pests, bad harvesting, poor storage facilities, poor transportation, and spoilage (Oke, 1972; Omolulu, 1972). The Nigerian way of eating also contributes to destruction of some nutrients. Due to lack of refrigeration soups last for 3 days in pots and are normally warmed 3 times a day to avoid spoilage. This may reduce the protein quality.

Diseases

In Nigeria P-C.M. often follows the occurrence of measles. For example, Ogbeide (1971) studied 52 P-C.M. cases in Ibadan and found that 67% of the children had a record of measles with 77% of the cases of measles occurring 3 months immediately preceding the onset of P-C.M. Toward the end of weaning at the age of 18 months, there is a peak in the incidence of measles in African children (Omolulu, 1972), which leads to anorexia and inability to suck from the breast. The mothers, therefore, turn to "force-feeding" with eko or gruel (the cooked form of ogi) and stop breast feeding. Thus eko (90% water and of poor protein and caloric value) is fed to the children 3 times daily. Invariably the child moves on to P-C.M. due to the long convalescence period when the child is force-fed on eko. Of the cases of P-C.M. occurring after measles in Nigeria, 98% of them follow this pattern of poor weaning (Omolulu, 1972). Also a study of case histories indicated that parents reported growth failure of their children after measles (Voorhoeve, 1966). The control of infectious disease reduced P-C.M. in the Ilesha area and resulted in increased height and weight (Edozien, 1970).

Customs

Many of the customs and beliefs of the Nigerian parents contribute to the nutritional problems of the children. For example, there is a general belief in Nigeria that eggs, meat, sweets, or other delicacies will make children steal (McCleans, 1966; Ogbeide, 1971; Oke, 1972). There is also the belief that eggs will cause diarrhea in children while meat and fruits are believed to cause worms (Oke, 1972).

Western Nigerian women have definite ideas concerning a number of foods which they think are bad for their children. Yams, a staple adult food, are considered to make a child sluggish and heavy and to delay walking and healthy growth. Peanuts are recognized as causing intestinal upsets and the same is true of sweet dishes (McCleans, 1966).

Customarily, food is distributed according to age and sex. The adults eat the best and largest portion but the husband has a choice before the wife. The older children choose the next best portion in size and quality, while the younger ones eat the portion left over.

Low Protein and Low Caloric Intake by Adults

The Nigerian diet is low in calories and protein (Edozien, 1965b, in Osifo, 1970). The staple foods in southern Nigeria are mainly tubers. For example, cassava, which is one of the principal staples, contains only 1 to 2% protein (USHEW/FAO, 1968). Very little food of animal origin is consumed in the south while the intake of legumes, nuts, green vegetables, and fruits is higher as compared with that of the north. However, cereal, meat, and milk are eaten in reasonable quantity in northern Nigeria (Nicol, 1959a; NSOIR, 1967; McFie, 1967).

According to data prepared by U.S. Foreign Agricultural Service for the years 1959 to 1961, when Nigeria had an estimated population of 39,400,000, cereal and starchy roots accounted for about 78% of the caloric intake. Meat and fish supplied less than 3% of the calories and about 8% of the protein while pulses and peanuts provided 6% of the protein (NSOIR, 1967). The quantity of milk produced or imported into Nigeria is not sufficient to meet the needs of the people.

Aall (1970) reports that before the Nigerian-Biafran war the general nutritional situation in southern Nigeria was critical. The protein consumption in the eastern Nigeria was 33g/day (50 to 65% of the 1968 recommended protein allowance) while that of the western Nigeria was 40 g/day (60 to 80% of the 1968 recommended protein allowance). On the other hand the protein consumption in northern Nigeria was 80 g/day which was adequate.

Malik (1967, in Oke, 1972), found that most Nigerian diets are low in sulphur-containing amino acids. Lysine, the second limiting amino acid, was deficient in the cooked form of all diets but not in the raw forms while tryptophan was the third limiting amino acid. The other amino acids appear to follow the FAO pattern.

Nutrition in Pregnancy and Lactation

An estimation of the food consumption of seven rural Nigerian peasant communities revealed that food was shared between adult women in such a way as to prevent any marked loss of weight during the usually prolonged period of lactation. Their diet also allowed a reasonable gain of weight in the last trimester of pregnancy (Nicol, 1959b; McFie, 1967). The concentrations of hemoglobin and plasma protein of women in the last trimester of pregnancy were lower than controls with the difference being more marked in the women on the low level of protein intake.

Woodruff (1951) estimated that pregnant women in Ibadan (a place with a high incidence of P-C.M.) never had more than 1 oz. (25g) of meat or fish a day and that the average intake of animal protein was 1 oz. every three or four days. Omolulu (1972), the director of Food Science and Applied Nutritition Unit, University of Ibadan, said that although many factors may account for low birth weight, there is no doubt that maternal malnutrition especially during the last trimester is the greatest cause of the low birth weight of the African child.

Weaning Practices

Growth studies in different parts of Africa have shown that the breast-fed African child grows at a faster rate than the child of the industrialized countries during the first four months of life due to the easy, relaxed, and complete breast-feeding that he enjoys (Thompson and Rahman, 1967; Omolulu, 1972).

According to Pate (1963, in Hendricks, 1964) during the post-weaning period mortality rates are 40 times higher in developing countries and this vast difference is due principally to nutritional factors.

In Nigeria babies are generally breast fed until they are 18 to 24 months old, with some supplementation with starchy foods after 4 to 6 months (Oke, 1972). After 18 to 24 months they are weaned onto wholly protein-poor adult diets, consisting principally of ogi, cassava, and yam (Ogbeide, 1971; Oke, 1972).

In the big cities of Nigeria, the period of weaning is much shorter and there is milk supplementation in many cases. In some cases mothers abandon artificial feeding partly because they cannot afford it and mainly on the excuse that it leads to diarrhea in their children, which may be due to poor sanitary practices (Oke, 1972). This leads to increased use of ogi.

Ogi

The traditional weaning food in Nigeria is ogi (Collis, 1966; Akinrele and Bassir, 1967; Akinrele and Edward, 1971; Osifo, 1971; Omolulu, 1972), which is a fermented slurry corn product. Collis (1966) stated that in the process of making ogi almost all the protein is poured off with the water, reducing the protein of corn from a normal of 7 to 9% down to 1.5 to 3%. Table 2 shows the analysis of corn and ogi by Akinrele and Bassir (1967), Oke (1972), and Osifo (1970). Akinrele and Bassir (1967) found no significant loss of protein in ogi. Oke (1972) found that ogi contained 6.88% protein as compared with 11.8% for the corn from which it is made.

Eko or gruel (the cooked form of ogi) is 90% water; at best it contains 0.5% protein and has a caloric value of 40 to 50 calories per 100 ml (Omolulu, 1972). In the analysis of ogi, Table 2, Osifo (1970) found that there is a loss of riboflavin and niacin in the making of ogi. According to Platt (1964, in Osifo, 1970), this vitamin loss is due to the uneven distribution of vitamins in the maize kernel and the vitamin-rich fractions are lost during the milling and sieving processes. On the basis of her findings, Osifo (1970) recommends the use of the whole corn instead of ogi.

A case history of 5 P-C.M. children, 1 to 2 years old with xerophthalmia, revealed that they had been fed on ogi with little breast feeding (Voorhoeve, 1966).

Table 2. Nutrient Values of the Maize Products (per 100 g dry weight)

		Maize[1]	Ogi[1]	Maize[2]	Ogi[2]	Maize[3]	Ogi[3]
Crude Protein	%	13.00	9.21	11.80	6.88	-	-
Fat	%	4.07	5.13	4.09	2.99	-	-
Crude Fiber	%	1.75	0.72	1.32	0.42	-	-
Soluble Carbohydrate (by difference)	%	77.56	84.28	82.56	89.26	-	-
Ash Content	%	3.62	0.66	3.68	0.45	-	-
Calcium	mg	186.00	76.60	0.10	0.05	-	-
Phosphorus	mg	333.50	183.50	0.38	0.08	-	-
Iron	mg	27.10	16.70	-	-	-	-
Thiamine (B_1)	mg	0.17	0.11	-	-	-	-
Riboflavin (B_2)	mg	0.20	0.08	-	-	0.12	0.05
Niacin (B_3)	mg	1.66	0.85	-	-	2.41	0.82
Pyridoxine (B_6)	mg	0.01	0.01	-	-	-	-
Folic Acid	mg	0.08	0.05	-	-	-	-
Ascorbic Acid (vitamin C)		0.0	0.0	-	-	-	-
Pantothenic Acid	mg	0.06	0.01	-	-	-	-
Vitamin A		0.0	0.0	-	-	-	-
Biological Value		54.75	43.57	-	-	-	-
		± 2.24	± 2.83	-	-	-	-
Net Protein Utilization		52.30	42.13	-	-	-	-
		± 2.86	± 2.90	-	-	-	-
Protein Efficiency Ratio		1.19	0.77	-	-	-	-
		± 0.01	± 0.01	-	-	-	-
True Digestibility Coefficient		95.48	96.71	-	-	-	-
		± 1.73	± 1.00	-	-	-	-

[1]Akinrele and Bassir (1967) [2]Oke (1972) [3]Osifo (1970)

Children's Diet

An estimation of seven rural Nigerian peasant communities revealed that children of ages 4 to 12 years were not given enough food to supply their calculated energy requirements, even though those over 12 years of age in the same community received adequate amounts (Nicol, 1959a). Protein intake of children ages 4 to 6 years was 56 g in the northern Nigeria as compared with 25 g in the eastern and western Nigeria (Oke, 1972). The recommended dietary allowance for 4- to 6-year-olds is 30 g protein (Bowes and Church, 1969). McFie (1967) found that in all areas of Nigeria there is evidence that the nutrient intake of children, in relation to their caloric requirements, is poorer than that of the adults.

Nicol (1959a) found that the overall incidence of P-C.M. in children up to 9 years old was 3.1%. In the north it was 2.2% and 5.3% in the south. The difference was not statistically significant ($P > 0.05$).

Until about 1965 no vital statistics were kept in Nigeria. Therefore, no accurate data were available until a team (NSOIR, 1967) estimated that about 50% of live born children live up to the age of 5. The following table by Oke (1972) shows that infant mortality for 1- to 4-year olds varies from 19 to 35% within the regions, with a mean of 22.7%

Table 3. Infant Mortality by Regions[1]

Source of Data	% Mortality				
	Urban	Rural	Infant Welfare Clinic	Dependent of Military Personnel	Average
Derived Savannah (Ilorin, Nsukka)		27.4	4		19.6
Savannah (Zaria)	(No figures available)				
Plateau (Jos)		45.6	26		35.8
Federal District (Lagos)			22.7		22.7
Rain Forest (Ibadan, Asaba)		26.3		16.9	21.6
Coastal (Epe, Port Harcourt)	13		17.4		13.7
Country Average					22.7

[1]Oke (1972)

Efforts in Nigeria to Overcome P-C.M.

Several processed food products have been produced. These include "Amama," a manufactured protein product. The acceptance was so low that it had to be taken off the market. "Arlac," which is composed of peanut flour, with 24% dried skimmed milk was produced at a so-called low cost, but the poor people who really needed it could not afford it. Milk products such as "lactogen" and "complan" are being used but only the well-to-do can afford them. "Soy-ogi" was produced and liked by the people (Akinrele and Edwards, 1971), but soybeans are very rare in Nigeria.

In northern Nigeria, a 3 to 1 mixture of peanut flour and skim milk powder was found effective in treating P-C.M. cases. A commercial preparation containing 85% peanut flour and 15% casein plus vitamins and minerals was useful in supplementing the diets of young children in Imesi, Western Nigeria (Aykroyd and Doughty, 1964).

During the Nigerian-Biafran war, a mixture of powdered skim milk and powdered egg was used in the nutrition clinics at the Abiniba Joint Hospital. In addition, the mothers were given demonstrations and lectures on local protein foods (Shellenberger, 1969).

Several nutritionists have encouraged the use of milk, meat, and eggs for the children. Some people have made recommendations concerning how to combat P-C.M. For instance, Oke (1972) recommended that the southerners should decrease their intake of yam and cassava and increase cereals, nuts, and pulses, which are 20% to 25% protein, and increase egg production so that the price of eggs would allow a consumption of about one egg per day per person. Omolulu (1972) felt that all efforts and plans for improving nutrition in Africa with packaged food like "Faffa," "Incaparina," etc., and from unicellular organisms will only be partially successful since the families in real need of them cannot afford the price, however small it may be. He felt the main solution will come by giving financial aid to the farmer to plant the needed foods.

CORN PROTEIN

The quantity of water-soluble protein is highest in "sweet corn," lowest in "dent" and "popcorn," and decreases as the plant approaches maturity (Peruanskii, 1958). Corn proteins are synthesized up to the beginning of the waxy stage of the plant, and then the protein begins to be converted into alcohol- and alkali-soluble fractions. With increased temperature the rate and degree of enzyme inactivation and the level of water-soluble proteins decreased (Bukhantsov and Sirko, 1970). At a temperature greater than 100°C. during the drying of corn, there was denaturation and a formation of dark particles was observed. It was accompanied by a decrease in fat content. The denaturation was an indirect measure of enzyme activity (Bukhantsov and Sirko, 1970).

Of the total protein in corn, most varieties contain 1.8 to

3.3% in the bran, hulls, or pericarp plus tips; the endosperm or white starchy portion contains 68.4 to 83.2%; while the germ or embryo contains 14.6 to 29.2% (Ricardo and Mertz, 1958). Numerous varieties of corn showed no major difference in amino acid composition (Ricardo and Mertz, 1958).

The highest nutritive value occurred in yellow corn (which had about the same nutritive value as white corn) collected during the last two phases of ripeness. The most valuable free amino acid and protein composition occurred in corn collected during the waxy seed ripeness stage (Baru, Medvedeva, and Miroshinichenko, 1970).

The protein of whole corn has been reported to be of low quality as measured biologically or by its content of essential amino acids (Oser, 1951; Redaksie, 1968). Lysine is the first limiting amino acid in corn (Kies, Fox, and Williams, 1967), and tryptophan is the next limiting amino acid (Bressani, Elias, and Gonez-Brenes, 1969). In corn protein the essential plus the unessential amino acids make up only 48% of the total nitrogen (FAO/WHO, 1965). Leucine is high in corn (Orr and Watt, 1968). Leucine accounts for 20% of the nitrogen supplied by essential and unessential amino acids (FAO/WHO, 1965), which may result in a protein imbalance (Cohlan and Stone, 1961).

A strain of corn that is homozygous for the recessive mutant gene called "opaque-2 corn" has been reported to contain more lysine and tryptophan (Mertz, Bates, and Nelson, 1964; Nelson, 1966; Frost and Robinson, 1971). Its protein efficiency ratio was 2.79 as compared with 2.88 for casein at comparable dietary protein levels (Bressani, Elias, and Gonez-Brenes, 1969). Surveys in Colombia among maize producers, marketers, and consumers showed that opaque-2 maize is not liked because it is unfamiliar. The farmers have difficulty in selling it, it is attacked more by insects when it is stored than flinty maize, and its floury texture does not suit traditional dishes (Pinstrup, 1972).

Opaque-2 corn is not produced in Nigeria and there is only a minimal amount of it for developmental purposes in certain parts of the world. When opaque-2 corn becomes sufficiently abundant, it will be interesting to test its acceptability in Nigeria. In the meantime, corn-based ogi, the principal weaning food in Nigeria (Collis, 1966; Akinrele and Bassir, 1967; Akinrele and Edward, 1971; Osifo, 1971; Omolulu, 1972), should be improved with culturally relevant and economically accessible foods.

Chapter 3

METHODOLOGY

THE ANALYSIS OF CORN AND OGI

The purpose of this experiment was to determine the protein composition of ogi and corn and their amino acid analysis.

Food Preparation

Ogi was prepared by soaking white corn from Mexico, as used in making ogi in Nigeria, in tap water for three to four days. The soaked corn was then wet-milled and sieved through a fine sifter with much water to remove the hulls. The filtrate was allowed to ferment at room temperature for three days. The supernatant was thrown away and the sediment dried in an air oven at 65 to 70°C. The dried ogi, as well as white corn from which it was made, was mechanically ground into powder. This same method was used in preparing corn and ogi wherever they were needed in experiments on the supplementation of corn and ogi diets.

Protein Determination

The protein content of corn and ogi was determined from a Kjeldahl digest by use of a nitrogen electrode (Orion Research Incorporation, 1972), as follows:

Kjeldahl Digest

In a 50 ml K flask put the following:

Potassium sulphate, 0.5 g

Selenium granules, 6-8

Sample e.g. corn flour, 0.2 g (or standard solution)

Concentrated sulfuric acid, 2 ml

Wrap filter paper around Hengar porous tube and insert into flask. Make sure closure is snug.

Set the temperature dial on the micro Kjeldahl apparatus at 2 for the first hour and gradually increase to 6.

Heat till the samples become colorless (about 8 hours), agitating flask periodically.

Cover with paraffin paper, when necessary, to continue another digest. Continue heating for another hour after flask contents are cleared.

Cool; dilute to 50 ml with distilled water.

Cover with paraffin paper and refrigerate.

Ammonia Electrode

(The digested ammonium salt must be neutralized to liberate ammonia gas. This reaction can produce a lot of heat, causing great variations in meter reading as it cools to room temperature. The refrigeration of the samples gives a lower initial temperature, resulting in a more consistent temperature.)

1. Agitate sample and pour into a 100 ml beaker. Add magnetic stirrer.

2. Place in water bath over stirrer (with asbestos between stirrer and bath).

3. Stir while adding 5 ml 10M sodium hydroxide (or whatever amount is necessary for a pH of 11-13. Use same quantity for all standards and unknown run that day.)

4. Dip electrode into distilled water. Blot dry with tissue paper.

5. Submerge lower end of electrode into sample.

6. Adjust temperature control to temperature expected at time of reading.

7. After 3 to 5 minutes, if needle is stable, read on "MV exp" scale.

The standard solutions for 500 ml, 1,000 ml, 2,000 ml, and 5,000 ml were determined and the readings plotted on a semi-logarithmic graph. The procedure for Kjeldahl digestion above (except that it is not necessary to heat the standard solution for digestion) and ammonia electrode were followed.

To calculate % protein in samples, multiply reading in mg from the standard curve by nitrogen factor and 100. Divide by the amount of sample used for Kjeldahl digestion in mg.

Routine methods (AOAC, 1970) were also employed by Warf

Institute, Inc., Madison, Wisconsin, for determinations of moisture, ash, fat, and fiber, and a repeated determination of protein. The carbohydrate was obtained by difference.

Amino Acid Determination

The amino acids were determined by the United Medical Laboratories Inc., Portland, Oregon, with ion-exchange chromatography (Speckman, Stein, and Moore, 1958) on a 50 mg of sample refluxed in 200 ml of 6NHCl during a 24-hour period, using a technicon amino acid analyzer.

THE COMPARISON OF THE PROTEIN QUALITY OF CORN AND OGI

In this experiment the protein of corn was compared with that of ogi by the rat growth method.

Diets

The three diet groups were corn, ogi, and casein (casein group served as control). These diets were isocaloric and contained 10% protein, 5% fat, 1.1% vitamin mixture (Nutritional Biochemicals Corporation), 2.5% Hegsted salts (Nutritional Biochemicals Corporation), and the balance as dextrin.

The foods were carefully weighed and thoroughly mixed in a Hobart mixer. The diets were kept refrigerated throughout the study in plastic-lined gallon-size cartons.

The protein content of the three diets was determined from a Kjeldahl digest by use of a nitrogen electrode (Orion Research Incorporation, 1972). See description in the experiment on the analysis of corn and ogi.

Laboratory Animals

Male weanling Sprague-Dawley albino rats from Simonson's Laboratories, Berkeley, California, were used for the experiment. The animals were divided into three groups so that the mean initial weight ranged from 51.3 g to 52.2 g, with 10 animals in each group. The animals were housed in individual raised-bottom wire cages in a room kept at 78^{O}F and 40 to 50% relative humidity. The lights were automatically turned on at 7:00 a.m. and off at 7:00 p.m. each day. Fisher porcelain food cups were used and food loss was minimized by placing these conicles in jars. Food and water were allowed *ad libitum*. Food consumption and weight gain were recorded weekly for a 4-week period.

Protein Efficiency Ratio

This is a measure of the amount of weight gain in relation to the amount of protein consumed. It was calculated for a 4-week period.

Analysis of Data

Following collection of data, it was compiled and transferred to data processing cards and submitted to statistical analysis. A one-way analysis of variance (Dixon and Massey, 1969) on the weight gain was done.

THE SUPPLEMENTATION OF CORN WITH BLACK-EYED PEAS AT VARIOUS PROTEIN LEVELS

The objective of this study was to determine the proportion of supplement needed for the experiment on the supplementation of corn and ogi with indigenous foods, by supplementing corn with black-eyed peas (BEP), which is the most practical in Nigeria of all the supplements.

Diets

The diet groups are shown in Table 4.

Table 4. Composition of Corn and Black-Eyed Pea (BEP) Diets

Diet Groups	% of Protein	
	BEP	Corn
1	100	-
2	80	20
3	60	40
4	40	60
5	20	80
6	-	100

The BEP was obtained locally and white corn from Mexico was used.

The diet composition and all the procedures in the experiment on the comparison of the protein quality of corn and ogi were the same as for this experiment, with the exception of the protein determination and the calculation of protein efficiency ratio. The mean initial weight of the animal ranged from 55.4 to 57.3 g. The data on weight gain was statistically analyzed by a one-way analysis of variance as done in the experiment on the analysis of corn and ogi.

Food Efficiency Ratio

Instead of the protein efficiency ratio in the experiment on the comparison of the protein quality of corn and ogi, food efficiency ratio was calculated. It is a measure of the amount of weight gain in relation to the amount of food eaten. It was calculated for a 4-week period.

THE SUPPLEMENTATION OF CORN AND OGI WITH INDIGENOUS FOODS

The supplementary value of inexpensive foods that are indigenous to Nigeria were investigated in this experiment, in reference to the improvement of the protein quality of corn and ogi.

Diets

The 21 diet groups are shown in Table 5.

The casein group was used as control. The egusi seed used was shipped by air freight from Nigeria. White corn from Mexico as traditionally used in Nigeria was used. Other foods were obtained locally and they include: La Loma peanut butter with no additives, powdered egg, black-eyed peas and soya flour. According to Osborne and Mendel (1917, in Leprovsky and Dimick, 1971), a raw soybean diet contains antitryptic factors. For this reason heat-treated soya flour was used. Since there is no antitryptic factor in raw black-eyed

Table 5. The Composition of Corn and Ogi Diets Supplemented with Indigenous Foods

Diet Groups	Percent of Total Protein				% Protein in Diet
	Staples	%	Supplements	%	
A	Corn	100		0	9.04
N	Ogi	100		0	8.64
B	Corn	60	Egusi	40	10.89
C	Corn	60	Peanuts	40	11.01
D	Corn	60	Soya flour	40	10.69
E	Corn	60	Egg	40	10.46
F	Corn	60	Black-eyed peas	40	10.75
G	Corn	60	Black-eyed peas	20	10.49
			Egusi	20	
H	Corn	60	Black-eyed peas	20	10.42
			Soya flour	20	
I	Corn	60	Black-eyed peas	20	10.46
			Egg	20	
J	Corn	60	Black-eyed peas	20	10.73
			Peanuts	20	
K	Corn	60	Black-eyed peas	13.3	10.41
			Peanuts	13.3	
			Egusi	13.3	
L	Corn	60	Black-eyed peas	13.3	10.15
			Peanuts	13.3	
			Soya flour	13.3	
M	Corn	60	Black-eyed peas	13.3	9.97
			Peanuts	13.3	
			Egg	13.3	
O	Ogi	60	Egusi	40	10.34
P	Ogi	60	Peanuts	40	10.46
Q	Ogi	60	Black-eyed peas	40	10.14
R	Ogi	60	Black-eyed peas	20	10.14
			Egusi	20	
S	Ogi	60	Black-eyed peas	20	10.42
			Peanuts	20	

Table 5 (continued)

Diet Groups	Percent of Total Protein: Staples	%	Supplements	%	% Protein in Diet
T	Ogi	60	Black-eyed peas	13.3	10.14
			Peanuts	13.3	
			Egusi	13.3	
	<u>Control</u>				
U	Casein	100		0	10.04

peas (Altschul, 1958), it was ground into powder. The egusi was roasted on the fire and ground as traditionally done in Nigeria. Corn and ogi were prepared as in the experiment on the analysis of corn and ogi.

The experimental procedure in this experiment was the same as in the experiment on the comparison of the protein quality of corn and ogi, except that food consumption was measured only during the last three weeks of the study. The same kind and amount of vitamins and minerals were added to these diets as in the experiment on the comparison of the protein quality of corn and ogi. All the diets contained 10.92% fat except diets A and N, which contained 5.2% fat. The mean initial weight of the animals ranged from 54.8 to 56.6 g.

Swim Test

This was done for the purpose of relating diet to physical endurance. At the end of the last weighing, each rat in groups A, F, N, and U (corn, corn plus BEP, ogi, and casein diet groups) was allowed a 10-minute swimming practice twice daily in a large plastic bucket with clean water at 75^{O}F. This practice was to allow all the rats to get used to swimming. After four days of practice swimming, metals weighing 10% of the rat's body weight were attached to the base of the tails of three rats (from different groups) to reduce the swim time, but the three tested rats swam indefinitely. The weights attached to the tail of the other rats were then increased to 15% body weight. When the rat sank under the water for 30 seconds or more, it was placed back in its cage, and the swim time on a stop watch was recorded. The three rats that were tried with 10% body weight attached to their tails were retested after 24 hours with 15% body weight attached to the base of their tails.

Organ Weight and Statistical Analysis

In this experiment the brain and right gastrocnemius muscle of groups A, F, N, and U (corn, corn plus BEP, ogi, casein diet groups) were excised and weighed after the swim test. The data on weight gain for the 21 groups of rats and the data on muscle weight and brain weight for groups A, F, N, and U were statistically analyzed by a one-way analysis of variance as was done in the experiment on the analysis of corn and ogi.

Chapter 4

RESULTS

THE ANALYSIS OF CORN AND OGI

Table 6 shows the proximate analysis of corn and ogi by Warf Institute, Inc., Madison, Wisconsin. On a dry weight basis corn contained 10.8% protein as compared with 10.3% in ogi. In this laboratory another series of 5 Kjeldahl digests per sample, using the nitrogen electrode (Orion Research Incorporation, 1972) was done. Corn contained 12.2% protein on a dry weight basis and was not much different from ogi containing 13.3% protein. On a dry weight basis the ash content of 1.3% in corn was about twice that in ogi, which was 0.6%. The fat, fiber, and carbohydrate contents were about the same in corn and ogi.

Table 6. Proximate Composition of Corn and Ogi

	As Is		Moisture-Free	
	Corn %	Ogi %	Corn %	Ogi %
Protein	9.4	10.0	10.8	10.3
Moisture	12.6	3.2	0.0	0.0
Ash	1.1	0.6	1.3	0.6
Fat	4.1	5.8	4.7	6.0
Fiber	1.9	2.2	2.2	2.3
Carbohydrate	70.9	78.2	81.1	80.8

The essential amino acid composition (Table 7), with the exception of leucine, tended to be decreased in ogi, while the non-essential amino acids tended to be increased. Tryptophan was destroyed by acid hydrolysis and therefore its value was not included in the table.

Table 7. Amino Acid Composition of Corn and Ogi

Amino Acid	Corn	Ogi
Essential Amino Acids	mg AA/g Food	
Threonine	34	29
Valine	51	45
Methionine	36	29
Phenylalanine	37	32
Lysine	17	15
Arginine	22	21
Histidine	12	12
Isoleucine	37	38
Leucine	95	106
Tryptophan	--	--
Nonessential Amino Acids		
Aspartic Acid	54	66
Serine	50	57
Glutamic Acid	120	142
Proline	73	82
Glycine	41	48
Alanine	73	82
Tyrosine	25	27
Taurine	40	40

THE COMPARISON OF THE PROTEIN QUALITY OF CORN AND OGI

Table 8 shows the growth for four weeks of animals on corn, ogi, and casein diets. This is shown graphically in Figure 3. Table 9 shows the mean weight gain and PER of these diet groups. The weight gain between all groups was significantly different ($P < .001$). The PER of ogi was 50% that of corn. Table 10 shows the result of a duplicate growth study (the experiment on the supplementation of corn and ogi with indigenous foods) with the same diets. The weight gain between all groups was again significantly different from each other ($P < .001$). The PER of ogi was 50% that of corn as previously found and only approximately 30% of the casein values in these two experiments. The mean brain weight of the ogi diet group was significantly less than the casein group ($P < .01$) and corn was significantly less than casein ($P < .01$). The muscle weight of the ogi diet group was significantly less than the casein group ($P < .001$).

Table 8. A Preliminary Experiment Showing the Mean Weight Gain of Rats on Corn, Ogi, and Casein Diets during a 4-week Period

Diet Groups	Diets	Protein %	Mean Weight Gain in Grams				
			1st week	2nd week	3rd week	4th week	Total
A_1	Corn	10.03	4.21	9.63	7.50	12.10	33.44
B_1	Ogi	10.03	0.79	3.87	2.60	4.00	11.26
C_1	Casein	10.89	17.52	21.06	14.90	26.70	80.18

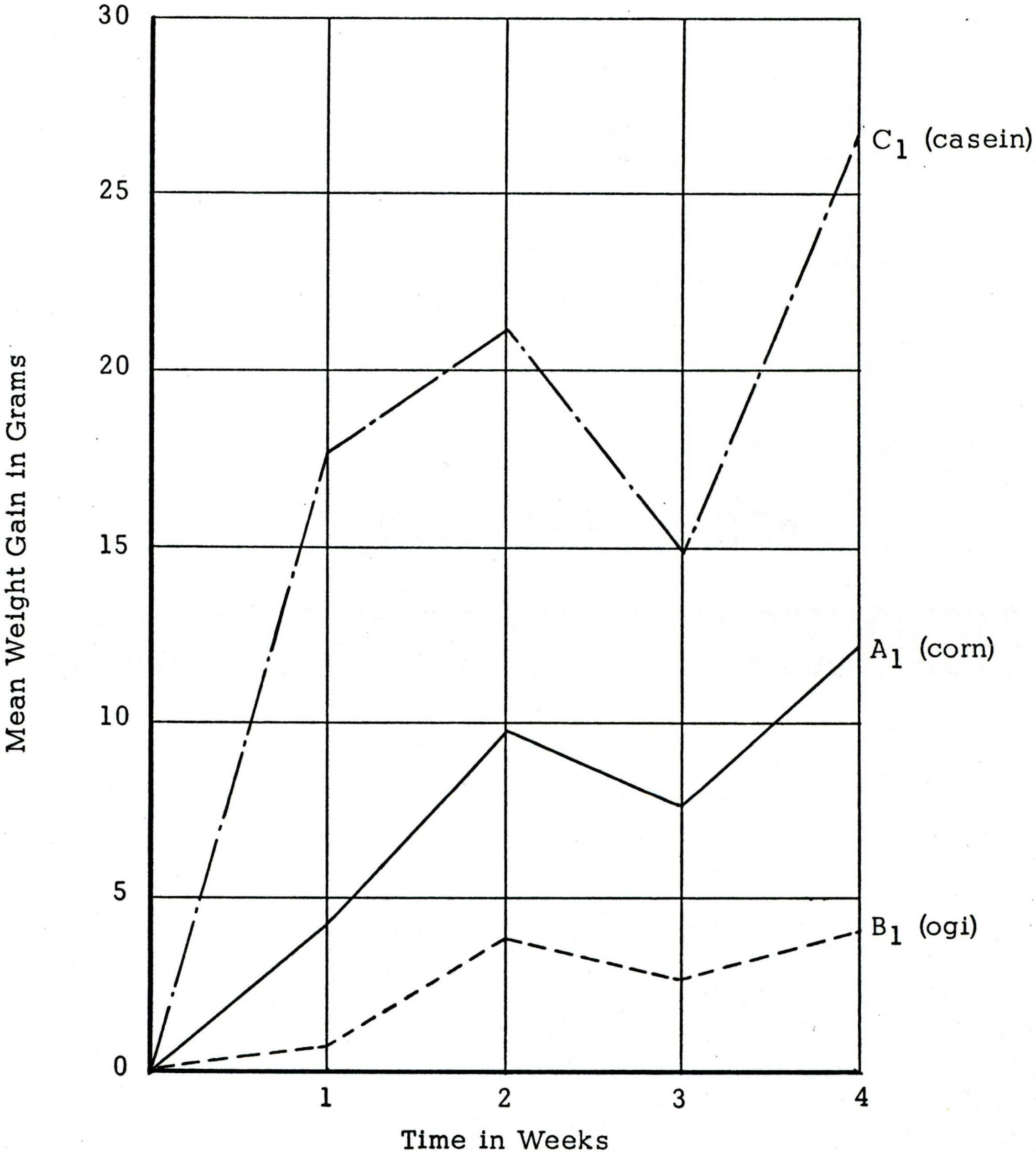

Figure 3. Growth of Rats on a Diet of Ogi, Corn, or Casein Fed at Protein Levels as Follows: Ogi = 10.03, Corn = 10.03, Casein = 10.89

Table 9. A Preliminary Experiment Showing the Mean Weight Gain of Rats during a 4-week Period and Protein Efficiency Ratio (PER) of Corn, Ogi, and Casein

Diet	% Protein	Weight Gain[a] g	Adjusted PER[b]
Corn	10.03	33.44 ±1.56	1.30
Ogi	10.03	11.26 ±0.99	0.66
Casein	10.89	80.18 ±4.10	2.50

[a]The weight gain for all groups was significantly different from each other ($p < .001$)
[b]Actual PER of Casein was 2.42

Table 10. Mean Weight Gain, Mean Brain and Gastrocnemius Weights of Rats During a 4-week Period and PER of Corn, Ogi, and Casein[a]

Diet	% Protein	Weight Gain g	Adjusted PER[b]	Brain Weight g	Muscle Weight g
Corn	9.04	36.11[c***] ±3.04	1.78	1.44[c**] ±0.05	0.46[c***] ±0.03
Ogi	8.64	10.80[c***,d***] ±0.85	0.89	1.50[c**] ±0.02	0.33[c***,d*] ±0.02
Casein	10.04	69.60[d***] ±5.55	2.50	1.67[d**] ±0.03	0.78[d***] ±0.03

[a]This data is part of the experiment on the supplementation of corn and ogi with indigenous foods. It is placed here for comparison with the preliminary experiment.
[b]PER values were for the last 3 weeks and the actual value for Casein was 2.30
[c]Significantly different from Casein: *$p < .05$, **$p < .01$, ***$p < .001$
[d]Significantly different from Corn: *$p < .05$, **$p < .01$, ***$p < .001$

THE SUPPLEMENTATION OF CORN WITH BLACK-EYED PEAS AT VARIOUS PROTEIN LEVELS

Table 11 shows the growth for four weeks of animals on different protein levels of corn and black-eyed pea (BEP) diets. This is shown graphically in Figure 4. Figure 5 shows a graphic presentation of different levels of percent protein in corn and BEP versus mean weight

Table 11. Mean Weight Gain of Rats on Different Levels of Corn and Black-eyed Pea (BEP) Diets during a 4-week Period

Diet Groups	% Total Protein BEP	% Total Protein Corn	Protein* %	Mean Weight Gain in Grams 1st week	2nd week	3rd week	4th week	Total
1	100	--	10	11.89	15.11	14.11	13.89	55.00
2	80	20	10	9.60	16.70	17.00	21.30	64.60
3	60	40	10	14.80	24.00	30.00	26.20	95.40
4	40	60	10	14.00	24.40	26.50	25.30	90.20
5	20	80	10	10.40	17.60	23.60	26.20	77.80
6	--	100	10	7.20	12.70	16.10	13.10	49.10

*Protein level was calculated from Bowes and Church (1969).

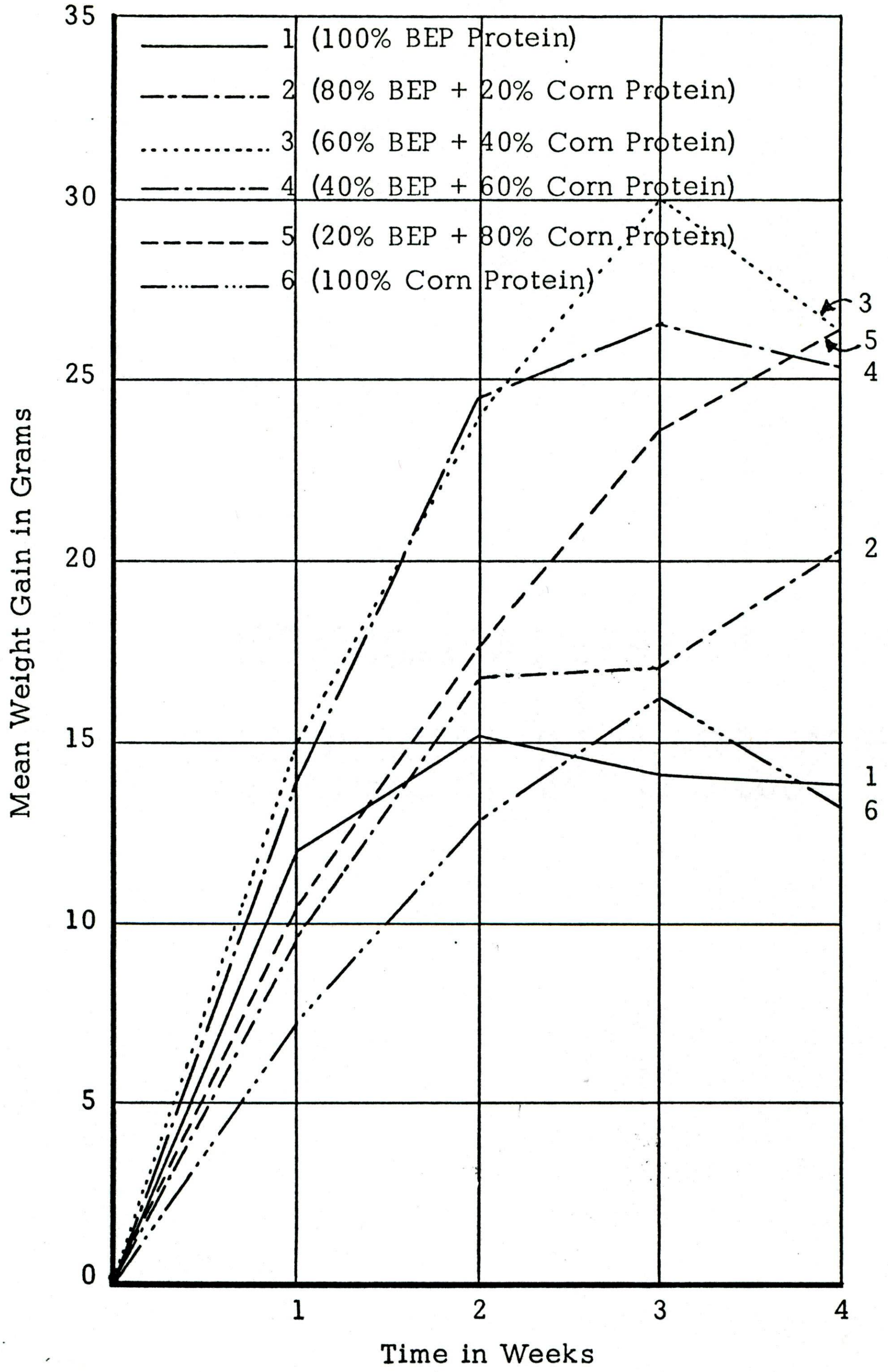

Figure 4. Growth of Rats on Diets Containing Varying Amounts of Protein from Corn and Black-eyed Peas (BEP)

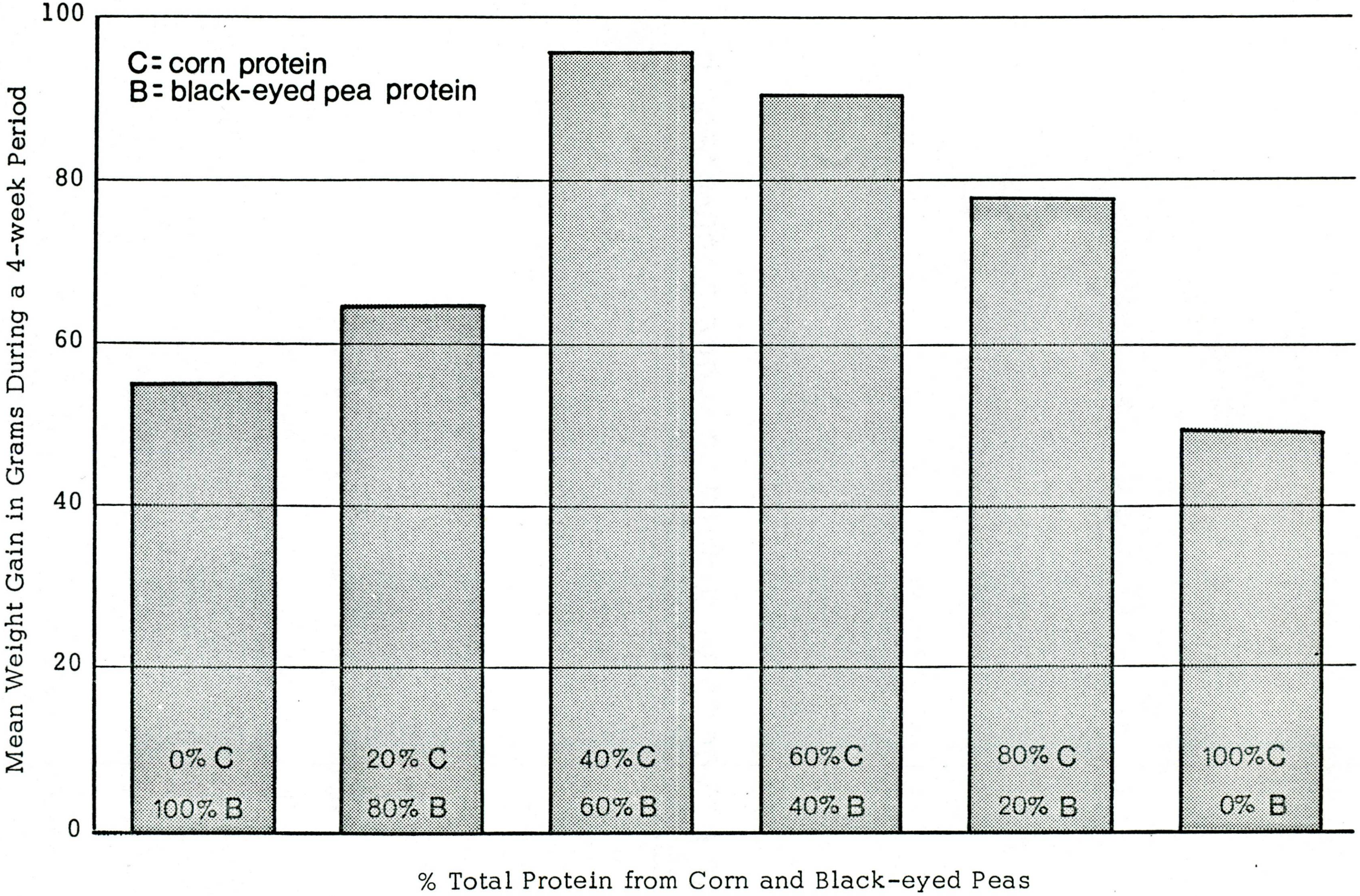

Figure 5. Total Weight Gain of Rats on Diets Consisting of Varying Quantities of Protein from Corn and Black-eyed Peas

gain. The bell-shaped curve shows the gradual increase in weight gain as corn and BEP supplement each other.

The mean weight gain of rats during a 4-week period and the Food Efficiency Ratio (FER) of rats on different levels of corn and BEP diets are shown in Table 12. There was a significant difference in weight gain between all groups ($P < .001$), with diet group 3 (60% BEP protein plus 40% corn protein) having the highest mean weight gain value of 95.4 g. There was no significant difference in weight gain between 100% BEP protein, 100% corn protein, and 80% BEP protein plus 20% corn protein (diet groups 1, 6, and 2), but 100% BEP protein and 100% corn protein (diet groups 1 and 6) were greatly improved with higher levels of supplementation: 60% corn protein plus 40% BEP protein (diet group 3) and 40% BEP protein plus 60% corn protein (diet group 4), ($P <.001$). The weight gain of diet group 5 (80% corn protein plus 20% BEP protein) was significantly greater than diet group 1 (100% BEP protein), ($P <.05$), and significantly greater than diet group 6 (100% corn protein), ($P <.01$). The level of supplementation in diet group 4 (40% BEP protein plus 60% corn protein) had the highest FER of 0.025. The weight gain of the rats in diet group 4 was much greater than that of diet groups 1 (100% BEP protein) and diet group 6 (100% corn protein), ($P < .001$). The weight gain of diet group 4 was also significantly greater than diet group 2 (80% BEP protein plus 20% corn protein), ($P < .05$). This data, as well as cost considerations, would indicate that diet group 4 would be the most desirable combination to serve the needs of the Nigerian population.

Table 12. The Mean Weight Gain of Rats during a 4-week Period and Food Efficiency Ratio (FER) of Rats on Different Levels of Corn and Black-eyed Pea (BEP) Diets

Diet Groups	% Total Protein BEP	Corn	Protein[a] %	Mean Weight Gain g	FER
1	100	--	10	55.00[b***] ±2.6	0.020
2	80	20	10	64.60[b*] ±4.3	0.021
3	60	40	10	95.40[c***,d***] ±4.5	0.024
4	40	60	10	90.20[c***,d***] ±5.5	0.025
5	20	80	10	77.80[c**,d*] ±5.2	0.022
6	--	100	10	49.10[b***] ±2.7	0.016

[a]Calculated protein level (Bowes and Church, 1969)

[b]Significantly different from Group 4 (60% corn protein and 40% BEP protein): $*p < .05$, $**p < .01$, $***p < .001$

[c]Significantly different from Group 1 (100% BEP protein): $*p < .05$, $**p < .01$, $***p < .001$

[d]Significantly different from Group 6 (100% corn protein): $*p < .05$, $**p < .01$, $***p < .001$

THE SUPPLEMENTATION OF CORN AND OGI WITH INDIGENOUS FOODS

Table 13 shows the growth of animals on corn or ogi diets with different levels of supplements during a 4-week period.

The effects of supplements on the mean weight gain of rats during a 4-week period and protein efficiency ratio (PER) of diets based on corn are shown in Table 14. There was a significant difference in weight gain between groups A to F (corn, corn plus egusi, corn plus peanuts, corn plus soya flour, corn plus eggs, and corn plus black-eyed peas [BEP]), ($P < .001$). The difference in weight gain between supplements B to F (corn plus egusi, corn plus peanuts, corn plus soya flour, corn plus eggs, and corn plus BEP) was significant, ($P < .001$). The addition of egusi (diet group B) to corn (diet group A) did not improve the weight gain of corn diet group, whereas the addition of peanuts (diet group C) to corn significantly improved the weight gain of corn diet group, ($P < .05$). The addition of soya flour, eggs, and BEP (diet groups D to F) further improved the weight gain of corn diet group, ($P < .001$). Soya flour, eggs, and BEP (diet groups D to F) supplemented corn about the same. The weight gain of diet group F (corn and BEP) was significantly greater than that of diet groups A (corn) and B (corn plus egusi), ($P < .001$), and diet group C (corn plus peanuts), ($P < .05$).

Table 15 shows the effects of supplements on the mean weight gain of rats during a 4-week period and PER of diets based on corn plus

Table 13. Mean Weight Gain of Rats on Corn or Ogi (Staple) Diets with Different Levels of Supplements during a 4-week Period

Diet Group	Percent of Total Protein: Staples Food	Staples %	Supplements Food	Supplements %	% Protein in Diet	Mean Weight Gain in Grams: Weeks 1st	2nd	3rd	4th	Total
A	Corn	100		0	9.04	4.33	6.20	10.55	15.00	36.11
N	Ogi	100		0	8.64	1.00	3.70	2.10	4.00	10.80
A	Corn	100		0	9.04	4.33	6.20	10.55	15.00	36.11
B	Corn	60	Egusi	40	10.89	4.20	7.10	9.20	14.50	35.00
C	Corn	60	Peanuts	40	11.01	8.00	11.60	15.00	22.70	57.30
D	Corn	60	Soya Fl.	40	10.69	16.80	24.30	28.50	29.80	99.40
E	Corn	60	Egg	40	10.46	16.30	24.50	28.90	29.00	98.70
F	Corn	60	BEP*	40	10.75	12.40	19.90	23.00	26.40	81.70
F	Corn	60	BEP	40	10.75	12.40	19.90	23.00	26.40	81.70
G	Corn	60	BEP	20	10.49	12.80	14.10	19.40	20.70	67.00
			Egusi	20						
H	Corn	60	BEP	20	10.42	20.70	20.90	30.60	28.20	100.40
			Soya Fl.	20						
I	Corn	60	BEP	20	10.46	14.70	20.90	30.50	31.70	97.80
			Egg	20						
J	Corn	60	BEP	20	10.73	12.30	12.60	19.30	25.20	69.40
			Peanuts	20						
J	Corn	60	BEP	20	10.73	12.30	12.60	19.30	25.20	69.40
			Peanuts	20						
K	Corn	60	BEP	13.3	10.41	9.40	11.40	18.60	22.60	62.00
			Peanuts	13.3						
			Egusi	13.3						

Table 13 (continued)

Diet Group	Staples Food	Staples %	Supplements Food	Supplements %	% Protein in Diet	1st	2nd	3rd	4th	Total
	Percent of Total Protein					Mean Weight Gain in Grams (Weeks)				
L	Corn	60	BEP	13.3	10.15	13.10	15.80	24.20	26.10	79.20
			Peanuts	13.3						
			Soya Fl.	13.3						
M	Corn	60	BEP	13.3	9.97	14.20	21.60	21.90	23.90	81.60
			Egg	13.3						
			Peanuts	13.3						
N	Ogi	100		0	8.64	1.00	3.70	2.10	4.00	10.80
O	Ogi	60	Egusi	40	10.34	3.40	6.90	7.00	9.00	26.30
P	Ogi	60	Peanuts	40	10.46	4.20	8.50	7.00	9.90	29.60
Q	Ogi	60	BEP	40	10.14	10.00	18.10	13.70	14.70	56.50
Q	Ogi	60	BEP	40	10.14	10.00	18.10	13.70	14.70	56.50
R	Ogi	60	BEP	20	10.14	7.30	11.00	8.80	12.20	39.30
			Egusi	20						
S	Ogi	60	BEP	20	10.42	9.20	15.80	13.20	14.60	52.80
			Peanuts	20						
R	Ogi	60	BEP	20	10.14	7.30	11.00	8.80	12.20	39.30
			Egusi	20						
T	Ogi	60	BEP	13.3	10.06	6.80	10.30	9.60	13.10	39.80
			Peanuts	13.3						
			Egusi	13.3						
U	Control Casein	100		0	10.04	17.00	14.40	14.10	24.00	69.60

*BEP: black-eyed peas

Table 14. The Effects of Supplements on the Mean Weight Gain of Rats During a 4-week Period and Protein Efficiency Ratio (PER) of Diets Based on Corn

	Diet Groups	Wt. Gain g	Adjusted PER*	% PER of casein	P levels for wt. gain comparison with diet A	diet F
A	corn	36.1±3.0	1.78	71.2		.001
B	corn + egusi	35.0±2.1	1.60	64.0	NS	.001
C	corn + peanuts	57.3±3.2	2.04	81.6	.05	.05
D	corn + soya flour	99.4±3.6	2.75	110.0	.001	NS
E	corn + eggs	98.7±5.3	2.92	116.0	.001	NS
F	corn + BEP	81.7±6.8	2.39	95.6	.001	

The weight gain between groups A to F was significantly different ($P < .001$)

The weight gain between the supplemented groups B to F was significantly different ($P < .001$)

*PER values were for the last 3 weeks and the actual PER for casein was 2.30

Table 15. The Effects of Supplements on the Mean Weight Gain of Rats During a 4-week Period and Protein Efficiency Ratio (PER) of Diets Based on Corn + Black-eyed Peas (BEP)

Diet Groups		Wt. Gain g	Adjusted PER*	% PER of casein	P levels for wt. gain comparison with diet F
F	corn + BEP	81.7±6.8	2.39	95.6	
G	corn + BEP + egusi	67.0±4.8	2.30	92.0	NS
H	corn + BEP + soya fl.	100.4±3.6	2.66	106.4	NS
I	corn + BEP + eggs	97.8±3.6	2.89	115.6	NS
J	corn + BEP + peanuts	69.4±6.5	2.41	96.4	NS

The weight gain between groups F to J was significantly different ($P<.001$)
The weight gain between the groups G to J with additional supplements was significantly different ($P<.001$)
*PER values were for the last 3 weeks and the actual PER for casein was 2.30

BEP. The difference in weight gain between these diet groups (F to J), which are the addition of egusi, soya flour, eggs, and peanuts to corn plus BEP, was significant, ($P < .001$). There was also a significant difference in weight gain between supplements of egusi, soya flour, eggs, and peanuts (diet groups G to J), ($P < .001$). The addition of egusi, soya flour, eggs, and peanuts to corn plus BEP (diet groups G to J), when compared individually with corn plus BEP, did not significantly improve the weight gain of corn plus BEP diet group.

In Table 16 the effects of supplements on the mean weight gain of rats during a 4-week period and PER of diets based on corn plus BEP plus peanuts are shown. The difference in weight gain between all diet groups (J to M), which are the addition of egusi, soya flour, and eggs to corn plus BEP plus peanuts, was significant, ($P < .05$). There was a significant difference in weight gain between supplements of egusi, soya flour, and eggs (diet groups K to M), ($P < .01$). The addition of egusi, soya flour, and eggs to corn plus BEP plus peanuts (diet groups K to M), when compared individually with corn plus BEP plus peanuts, did not significantly improve the weight gain of corn plus BEP plus peanuts diet group (J).

The effects of supplements on the mean weight gain of rats during a 4-week period and PER of diets based on ogi are shown in Table 17. There was a significant difference in weight gain between all the groups (N to Q), which are ogi, ogi plus egusi, ogi plus peanuts, and ogi plus BEP, ($P < .001$). There was also a significant difference in

Table 16. The Effects of Supplements on the Mean Weight Gain of Rats During a 4-week Period and Protein Efficiency Ratio (PER) of Diets Based on Corn + Black-eyed Peas (BEP) + Peanuts

Diet Groups	Wt. Gain g	Adjusted PER*	% PER of casein	P levels for wt. gain comparison with diet J
J corn + BEP + peanuts	69.4±6.5	2.41	96.4	
K corn + BEP + peanuts + egusi	62.0±2.3	2.32	96.0	NS
L corn + BEP + peanuts + soya fl.	79.2±5.8	2.72	108.8	NS
M corn + BEP + peanuts + eggs	81.6±4.4	2.72	108.8	NS

The weight gain between groups J to M was significantly different ($P < .05$)
The weight gain between the groups K, L, and M with additional supplements was significantly different ($P < .01$)
*PER values were for the last 3 weeks and the actual PER for casein was 2.30

Table 17. The Effects of Supplements on the Mean Weight Gain of Rats During a 4-week Period and Protein Efficiency Ratio (PER) of Diets Based on Ogi

Diet Groups		Wt. Gain g	Adjusted PER*	% PER of casein	P levels for wt. gain comparison with diet N	diet Q
N	ogi	10.8±0.9	0.89	35.6		.001
O	ogi + egusi	26.3±1.4	1.54	61.6	.001	.001
P	ogi + peanuts	29.6±1.4	1.47	58.8	.001	.001
Q	ogi + BEP	56.5±2.7	2.29	91.6	.001	

The weight gain between groups N to Q was significantly different ($P < .001$)
The weight gain between the supplemented groups O, P, and Q was significantly different ($P < .001$)
*PER values were for the last 3 weeks and the actual PER for casein was 2.30

weight gain between supplements of egusi, peanuts, and BEP (diet groups O to Q), ($P < .001$). The weight gain of ogi diet group (N) was significantly improved with the addition of egusi, peanuts, and BEP (diet groups O to Q), ($P < .001$). The mean weight gain of diet group Q (ogi plus BEP) was significantly greater than the rest of the groups, which are ogi, ogi plus egusi, and ogi plus peanuts.

Table 18 shows the effects of supplements on the mean weight gain of rats during a 4-week period and PER of diets based on ogi plus BEP. There was a significant difference in weight gain between the three groups (Q to S), ($P < .001$). There was also a significant difference in weight gain between diet groups R and S (the addition of egusi and peanuts to ogi plus BEP), ($P < .01$). The addition of peanuts to ogi plus BEP (diet group S) did not improve the weight gain of ogi plus BEP diet group (Q), whereas the addition of egusi to ogi plus BEP diet group (R) decreased the weight gain of ogi plus BEP diet group (Q), ($P < .001$).

The supplementation of ogi plus BEP plus egusi (diet group R) with peanuts (diet group T) did not improve the weight gain of the rats on these diets (Table 19).

Table 20 shows selected diet groups from Tables 14 to 19 that indicate the rats' mean weight gain, PER, and % PER of casein on corn and ogi diets supplemented with indigenous foods. This table includes the swim time, mean weight gain, mean brain and gastrocnemius muscle weights of rats during a 4-week period, and PER of corn, ogi, corn and BEP, and casein. A graphical presentation of the mean weight gain of

Table 18. The Effects of Supplements on the Mean Weight Gain of Rats During a 4-week Period and Protein Efficiency Ratio (PER) of Diets Based on Ogi + Black-eyed Peas (BEP)

Diet Groups	Wt. Gain g	Adjusted PER*	% PER of casein	P levels for wt. gain comparison with diet Q
Q ogi + BEP	56.5 ± 2.7	2.29	91.6	
R ogi + BEP + egusi	39.3 ± 2.0	1.89	75.6	.001
S ogi + BEP + peanuts	52.8 ± 3.9	2.08	83.2	NS

The weight gain between groups Q, R, and S was significantly different ($P < .001$)

The weight gain between the groups R and S with additional supplements was significantly different ($P < .01$)

*PER values were for the last 3 weeks and the actual PER for casein was 2.30

Table 19. The Effects of Supplements on the Mean Weight Gain of Rats During a 4-week Period and Protein Efficiency Ratio (PER) of Diets Based on Ogi + Black-eyed Peas (BEP) + Egusi

Diet Groups	Wt. Gain g	Adjusted PER*	% PER of casein
R ogi + BEP + egusi	39.3±2.0	1.89	75.6
T ogi + BEP + egusi + peanuts	39.8±2.3	1.95	78.0

There was no significant difference in weight gain between groups R and T

*PER values were for the last 3 weeks and the actual PER for casein was 2.30

Table 20. Swim Time, Mean Weight Gain, Mean Brain and Gastrocnemius Muscle Weights of Rats during a 4-week Period and PER of Corn, Ogi, Corn + Black-eyed Peas (BEP), and Casein

Diet	% Protein	Weight Gain in g	Adjusted PER[a]	Brain Weight in g	Muscle Weight in g	Swim Time in Minutes
Corn	9.04	36.11[b*** c***] $\pm$3.04	1.78	1.44[b** c*] $\pm$0.05	0.46[b*** c***] $\pm$0.03	1.46 $\pm$0.35
Ogi	8.64	10.80[b*** d*** c***] $\pm$0.85	0.89	1.50[b**] $\pm$0.02	0.33[b*** d* c***] $\pm$0.02	1.89 $\pm$0.51
Corn + BEP	10.75	81.70[d***] $\pm$6.83	2.39	1.60[d*] $\pm$0.03	0.74[d***] $\pm$0.05	1.69 $\pm$0.51
Casein	10.04	69.6[d***] $\pm$5.55	2.50	1.67[d**] $\pm$0.03	0.78[d***] $\pm$0.03	1.33 $\pm$0.62

[a]PER values were for the last 3 weeks and the actual value for casein was 2.30

[b]Significantly different from casein: *P <.05, **P <.01, ***P <.001

[c]Significantly different from corn + BEP: *P <.05, **P <.01, ***P <.001

[d]Significantly different from corn: *P <.05, **P <.01, ***P <.001

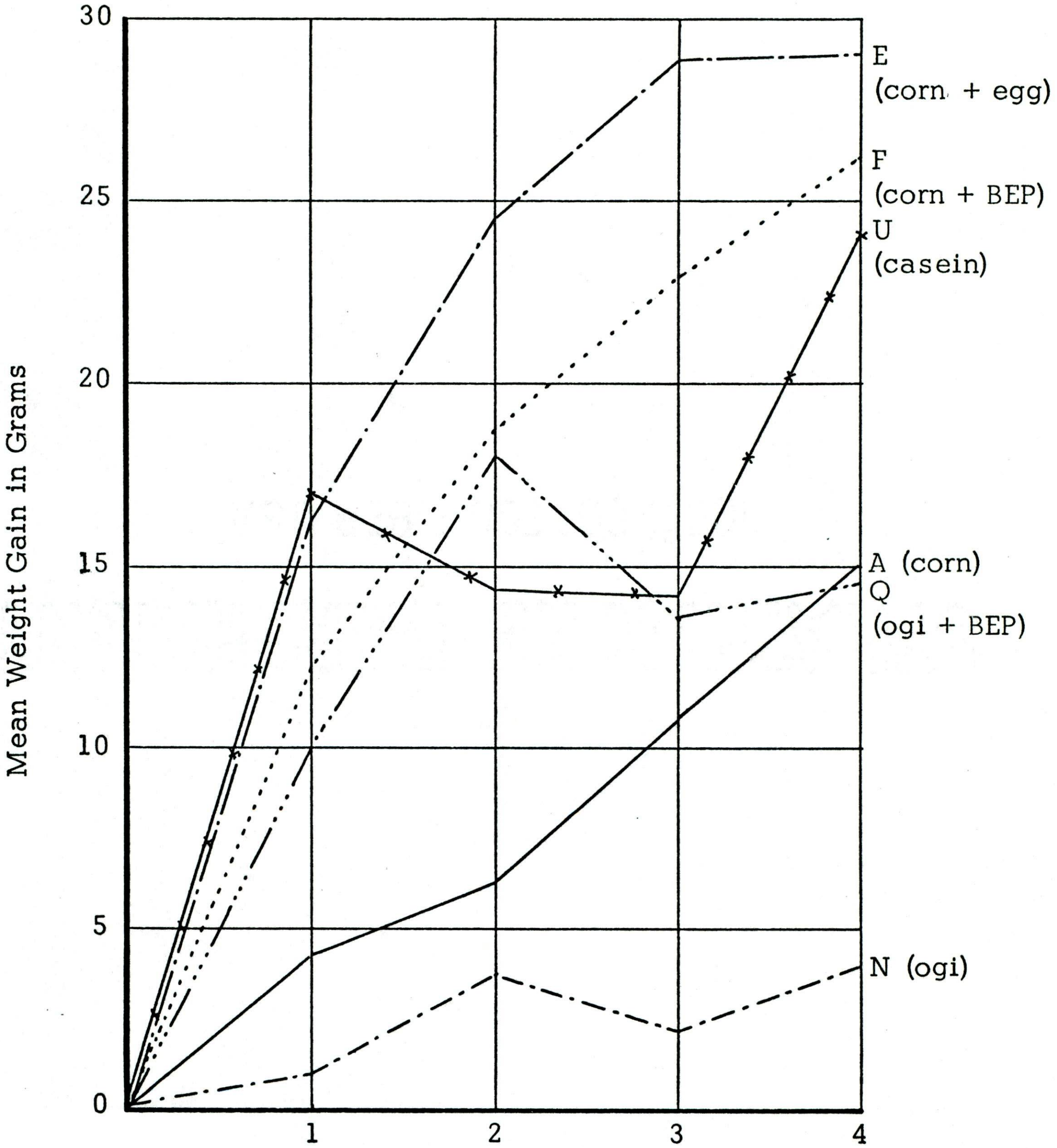

Figure 6. Growth of Rats on a Diet of Corn Supplemented with Egg and with Black-eyed Peas (BEP), Casein, Corn, Ogi Supplemented with BEP, and Ogi Fed at about 10% Protein Level

six selected diets from Tables 14 to 19 (Figure 6) are shown. There was a significant difference between the groups in weight gain, brain weight and gastrocnemius muscle weight (P <.001).

The weight gain for corn and ogi diet groups in Table 20 were significantly different from casein and corn plus BEP diet groups, (P <.001). There was no significant difference in weight gain, brain weight, and gastrocnemius muscle weight between casein and corn plus BEP diet groups. The mean brain weight of the corn diet group was significantly less than the casein group, (P <.01), and the corn plus BEP diet group, (P <.05). The mean brain weight of the corn plus BEP diet group was significantly greater than the corn group, (P <.05). The muscle weight of the ogi diet group was significantly less than the corn group, (P <.05), and the casein and corn plus BEP diet groups, (P <.001). The muscle weight of the corn group was significantly less than the casein and the corn plus BEP diet groups, (P <.001). There was no significant difference in swim time, which indicates in this study that the swim time was not related to protein quality. The PER of ogi was 50% of corn as previously mentioned and only about 30% of the casein and the corn plus BEP diet groups.

Table 21 is a comparison of the mean weight gain of rats on corn and ogi diets supplemented with indigenous foods. In comparing the figures in Table 21A, there was a significant difference, (P <.001), when ogi and corn groups were supplemented with single foods. A comparison of the same supplements (egusi, peanuts, and BEP) in both

Table 21. A Comparison of the Mean Weight Gain of Rats on Corn and Ogi Diets, Supplemented with Indigenous Foods

	Supplements	Ogi	Corn
A	None	10.78	36.11
	Egusi	26.30	35.00
	Peanuts	29.60	57.30
	BEP*	56.50	81.70

The difference between ogi and corn groups was significant ($P < .001$)

The difference between the supplements was significant ($P < .001$)

	Supplements	Ogi	Corn
B	BEP	56.5	81.7
	BEP + egusi	39.3	67.0
	BEP + peanuts	52.8	69.4

The difference between ogi and corn groups was significant ($P < .01$)

The difference between supplements was significant ($P < .001$)

	Supplements	Ogi	Corn
C	BEP + egusi	39.3	67.0
	BEP + egusi + peanuts	39.8	67.0

The difference between ogi and corn groups was significant ($P < .001$)

There was no significant difference between the supplements

*Black-eyed peas

groups shows that the corn diet groups were significantly greater than the ogi diet groups, ($P < .001$).

There was a significant difference between the groups, ($P < .01$), when ogi and corn were supplemented with BEP, BEP plus egusi, and BEP plus peanuts (Table 21B). A comparison between the same supplements (BEP, BEP plus egusi, and BEP plus peanuts) in both groups reveal that the corn diet groups were again significantly greater than the ogi diet groups, ($P < .001$).

As can be seen in Table 21C, there was a significant difference, ($P < .001$), between ogi and corn groups when supplemented with BEP plus egusi and BEP plus egusi plus peanuts. But there was no significant difference between the supplements (BEP plus egusi and BEP plus egusi plus peanuts).

Chapter 5

DISCUSSION

The protein content of corn was not different from that of the ogi, which is traditionally allowed to ferment as done in this study. This finding is in contrast to Collis (1966) who stated that the protein in ogi was only one third that of corn. Oke (1972) found corn to contain 70% more protein than ogi. Akinrele and Bassir (1967) found no significant loss of protein in making ogi. The data in this experiment are consistent with this latter report.

While there was no apparent change in the content of protein in the making of ogi, there was a profound decrease in the protein quality. The PER of ogi was 50% of corn and about 30% of casein. Akinrele and Bassir (1967) also found the PER of ogi to be only half that of corn. They found, however, that the protein content of the traditionally fermented ogi was greater compared with an experimental ogi that was not fermented. Unfortunately, the unfermented ogi was not tested in this experiment. Schultz and Thomas (1949) suggest that wet milling of corn germ as compared with dry milling reduces the biological value of corn due to poor absorption and digestibility. However, the reported (Akinrele and Bassir, 1967) digestibility for corn (95) and ogi (97) was the same, even though the biological value was much lower for ogi (44) as compared with corn (55 to 60). The total essential amino acid content tended to be lower in ogi than corn. In contrast, the leucine content, normally high in corn (Orr and Watt, 1968), was increased in ogi. This may result in an imbalanced protein with a resulting poor protein quality (Cohlan and Stone, 1961). Both the washing of corn in making ogi and the bacterial growth may influence the amino acid content of ogi. These changes in amino acid content may explain the reduction in protein quality from corn to ogi.

The ash content of ogi was only half that of corn, suggesting a high loss of minerals. Table 2 shows that the mineral content of corn was reduced in the process of making ogi (Akinrele and Bassir, 1967; Oke, 1972). Moreover, those vitamins that were tested were also decreased in ogi (Akinrele and Bassir, 1967; Osifo, 1970).

The recommended biological value of diets for adults is 60 and 70 for infants (NRC, 1959). The biological value for corn is between 55 and 60 (Akinrele and Bassir, 1967; FAO, 1970), and that of ogi is only 44 (Akinrele and Bassir, 1967). The high mortality and morbidity among infants due to protein-calorie malnutrition is attributed to the large use of ogi as a weaning food by many Nigerian women (Collis, 1966; Akinrele and Bassir, 1967; Akinrele and Edward, 1971; Osifo, 1971; Omolulu, 1972). The results of this study clearly show that the quality of protein is markedly decreased in corn during the preparation of ogi. Other nutrients are also reduced in the process of making ogi (Akinrele and Bassir, 1967; Osifo, 1971; Oke, 1972). It seems that if the incidence of protein-calorie malnutrition is to be decreased in Nigeria, the nutritive value of ogi must be substantially improved. For this reason ogi was supplemented with foods that were previously used with adult Nigerian diets according to the criteria of taste, adequate nutrition, economy, and availability.

The experiment on the supplementation of corn and black-eyed peas (BEP) at various protein levels shows a profound increase in the food efficiency ratio (FER) of corn from 0.016 to 0.024 by combining 60% corn protein with 40% BEP protein. This level of supplementation was therefore used to supplement ogi with foods available in Nigeria.

Of the 18 ogi or corn diets that were supplemented, 11 of them had an adjusted PER value of 2.29 to 2.92 (92 to 116% of the PER of casein), which suggests a good protein quality. The diet which contained 60% corn protein and 40% egg protein had the highest adjusted PER value of 2.92. But because eggs are high in cholesterol and saturated fatty acids, a high consumption may not be best, since this might lead to atherosclerosis in later life. Besides this, eggs are expensive in Nigeria (Van-Veen, 1964; McClean, 1966; Edozien, 1970); therefore their continuous use may not be acceptable.

Another good combination was 60% corn protein and 40% soya flour protein, with an adjusted PER value of 2.75. But soya beans are not yet available in Nigeria. Although imported soya flour can be used, Omolulu (1972) pointed out the fact that imported foods cannot solve the problem of P-C.M. in Nigeria. This is because they cannot be produced at such a low cost that the poor Nigerian who needs them most can afford them. One of the foods that supplemented corn very well was BEP. In this study, such a diet contained 60% corn protein plus 40% BEP protein with an adjusted PER of 2.39 or 60% ogi protein plus 40% BEP protein with an adjusted PER of 2.29. Akinrele and Edward (1971) found the adjusted PER of 30% soya flour plus 70% ogi product (soy-ogi) to be 2.2, which was similar to that of 60% ogi protein plus 40% BEP protein. They also found the biologic value of soy-ogi to be 91.3 while that of casein was 88.5

A 60% corn protein plus 40% BEP protein will be 25% total dry BEP plus 75% dry corn by volume. This will provide a diet with about 14% of the calories as dietary protein, which will more than meet the recommended dietary allowance of 10% dietary calories from protein for children (Bowes and Church, 1969). Akinrele and Edwards (1971) indicated that soy-ogi was liked by those who tried it and that it helped in the recovery of kwashiorkor babies. If the addition of 30% soya flour by dry weight (which is not familiar) to the traditional weaning food (ogi) was acceptable, it is certain that the addition of a 25% dry BEP (which is commonly used by the Nigerians) to 75% dry corn or ogi by volume will also be acceptable. The combination of 1/4 cup BEP dry weight to 3/4 cup corn is simple and the poor mother in Nigeria can purchase corn and BEP and make her own combinations if educated to do so. Therefore, 1/4 cup BEP plus 3/4 cup corn fulfills the objective of this research because it is indigenous, easily grown in Nigeria, available in the local markets, used by the people, and within the economic capacity of the people.

The fact that 11 diets in this experiment have excellent PER values shows that there are many possible ways of combining Nigerian foods to obtain adequate protein for the children. Therefore this study could be the basis for nutrition education programs throughout Nigeria.

Chapter 6

SUMMARY AND CONCLUSIONS

The nutritive value as well as the protein and amino acid composition of ogi (the major Nigerian weaning food) were determined and compared with those of corn. Ogi and corn, from which ogi is made, contained about the same amount of protein but ogi contained half as much ash. The weight gain and the PER of the rats fed ogi were about half that of those rats fed corn. This great drop in the protein quality of ogi may be the result of a lowered amino acid composition of ogi, as compared to corn. In addition, leucine, an essential amino acid already high in corn, was increased in ogi.

In order to improve the protein quality of ogi, the supplementary value of other inexpensive foods that are indigenous to Nigeria was investigated. Of the 18 ogi diets that were supplemented, 11 of them had an adjusted PER value of 2.29 to 2.92 (92 to 116% of the PER of casein), which suggests a good protein quality. The diet that contained 60% black-eyed pea protein and the 40% corn protein with PER of 2.39 (95.6% of the PER of casein) was found to be least expensive. It also fulfills the other objectives of this research, namely, adequate nutrition, acceptability, and availability.

The fact that 11 diets in this experiment have excellent PER values shows that there are many possible ways of combining Nigerian foods to obtain adequate protein for the children. Hopefully this study will be the basis for nutrition education programs for Nigeria.

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LOMA LINDA UNIVERSITY

Graduate School

THE NUTRITIVE VALUE AND SUPPLEMENTATION OF OGI

(PAP), THE MAJOR NIGERIAN WEANING FOOD

by

Elizabeth E. Gyaami

An Abstract of a Thesis

in Partial Fulfillment of the Requirements

for the Degree Master of Science

in the Field of Dietetics

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ABSTRACT

The purpose of this study was to evaluate the nutritive value of ogi, which is the national weaning food in Nigeria, and to supplement it with indigenous foods that are easily produced in Nigeria, available in the local market, locally used, and within the economic capacity of the people. The protein content of corn and ogi was determined by the Kjeldahl method and the amino acid content was determined by ion-exchange chromatography. The quality of the foods was evaluated by the rat growth method and the protein efficiency ratio (PER).

Ogi and corn, from which ogi is made, contained essentially the same amount of protein but ogi contained only half as much ash. The 4-week growth of rats fed ogi (11 g) was significantly less ($P < .001$) than corn-fed rats (33 to 36 g), and the latter was significantly less ($P < .001$) than the casein-fed rats (70 to 80 g). The PER values for ogi (0.66 to 0.89) were only half of that for corn (1.30 to 1.78) and one third of the adjusted casein value (2.50). This great drop in the nutritive value of ogi as compared with corn may be the result of the amino acid composition of ogi, which tends to be higher in leucine, an essential amino acid already high in corn, and lower in the other essential amino acids. These data suggest that if the high incidence of

malnutrition in Nigeria is to be reduced, measures must be taken to improve the nutritive value of ogi.

Therefore, ogi and corn flour were supplemented with indigenous foods. The best level of supplement was found to be 60% corn protein plus 40% supplementary protein. In the experiment on the supplementation of corn and ogi with indigenous foods there were 18 diets containing various levels of egusi, black-eyed peas, peanuts, soya flour, and egg. The mean weight gain of the rats on these diets was 26.3 g to 99.4 g as compared with 10.8 g for ogi. A comparable ogi diet group was significantly less than the same diet containing corn ($P < .001$). Of the 18 diets, 11 had excellent adjusted PERs of 2.29 to 2.92. According to the findings in this experiment, the diet containing 60% corn protein plus 40% BEP protein was found to be the best. It also meets the objective of this research, namely, adequate nutrition, acceptability, availability, and economy. Therefore this study provides a rationale for nutrition educational programs for Nigeria.